EXHIBIT 1

FIFTH MODIFICATION OF CONSENT DECREE

IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF MICHIGAN
SOUTHERN DIVISION

UNITED STATES OF AMERICA,	)	
Plaintiff,	)	
v.	)	
ENBRIDGE ENERGY, LIMITED PARTNERSHIP,	)	
ENBRIDGE PIPELINES (LAKEHEAD) L.L.C.,	)	**Civil Action No. 1:16-cv-914**
ENBRIDGE ENERGY PARTNERS, L.P.,	)	
ENBRIDGE ENERGY MANAGEMENT, L.L.C.,	)	**Judge Gordon J. Quist**
ENBRIDGE ENERGY COMPANY, INC.,	)	
ENBRIDGE EMPLOYEE SERVICES, INC.,	)	
ENBRIDGE OPERATIONAL SERVICES, INC.,	)	
ENBRIDGE PIPELINES INC., and	)	
ENBRIDGE EMPLOYEE SERVICES CANADA INC.,	)	
Defendants.	)	

FIFTH MODIFICATION OF CONSENT DECREE

WHEREAS, the United States of America, on behalf of the United States Environmental Protection Agency ("EPA") and the United States Coast Guard, filed a complaint in this matter on July 20, 2016, asserting claims against Enbridge Energy, Limited Partnership and several affiliated entities (hereinafter collectively referred to as "Enbridge") under the Clean Water Act, 33 U.S.C. § 1251 *et seq.*, and the Oil Pollution Act, 33 U.S.C. § 2701 *et seq.*, arising from two 2010 oil transmission pipeline failures that resulted in discharges of oil into waters of the United States.

WHEREAS, on May 23, 2017, this Court approved and entered a Consent Decree resolving claims that the United States asserted against Enbridge in this action.

WHEREAS, the Consent Decree establishes numerous requirements applicable to fourteen separate oil transmission pipelines in the United States owned and operated by Enbridge known as the "Lakehead System."

WHEREAS, Section VII.D of the Consent Decree includes provisions pertaining to an In-Line Inspection ("ILI") Based Spill Prevention Program, including provisions that define and require identification of certain Priority Features, provisions that establish deadlines for Initial ILI Reports upon completion of required ILIs, and provisions governing the identification, excavation, and mitigation or repair of Features Requiring Excavation.

WHEREAS, the ILI Based Spill Prevention Program in the Consent Decree requires Enbridge to timely identify and evaluate Crack features, Corrosion features, and Geometric features (including dents) detected on Lakehead System pipelines, including intersecting features such as dents that intersect with corrosion.

WHEREAS, the ILI Based Spill Prevention Program in the Consent Decree requires Enbridge to, among other things: perform periodic ILI Tool Runs on each Lakehead System pipeline to identify different types of features that could pose a threat of a pipeline rupture or leak; complete a timely evaluation of any data quality issues relating to information obtained from each ILI Tool Run; identify features that require excavation and repair or mitigation, based on criteria set forth in the Consent Decree, and place such features on a Dig List; repair or mitigate features on the Dig List within specified time frames; establish and maintain pressure restrictions for certain features on the Dig List; and maintain data associated with each ILI Tool Run.

WHEREAS, since entry of the Consent Decree, Enbridge has developed and refined methods for evaluating potential threats associated with dents that intersect with corrosion, including a screening-level evaluation of risk based on a semi-quantitative analysis of dents method ("SQuAD") and a more detailed evaluation of risk based on a quantitative analysis of dents method ("QuAD").

WHEREAS, the Independent Third Party ("ITP") retained pursuant to Paragraph 125 of the Consent Decree has evaluated the SQuAD and QuAD methodologies described in attached Appendices G and H, and, on the basis of such evaluation, the ITP has concluded that these methodologies provide a reliable means for evaluating intersecting dent-and-Corrosion features and making timely determinations regarding which intersecting dent-and-Corrosion features pose an unacceptable likelihood of a pipeline rupture or leak.

WHEREAS, based on a review of relevant information regarding intersecting dent-and-Corrosion features on Lakehead System pipelines, the ITP concurs that the SQuAD methodology (as described in proposed Appendix G to the Consent Decree) will provide a conservative identification of those intersecting dent-and-Corrosion features that could present a potential threat of a pipeline rupture or leak.

WHEREAS, QuAD is a Finite Element Analysis ("FEA") method combined with an analysis that accounts for uncertainties associated with pipe properties and ILI tool measurements. The QuAD methodology is used to evaluate the strain, burst, and fatigue limit states of intersecting dent-and-Corrosion features and establish a strain safety factor, a burst pressure safety factor, and a fatigue safety factor for each evaluated intersecting dent-and-Corrosion feature.

WHEREAS, based on a review of relevant information regarding intersecting dent-and-Corrosion features on Lakehead System pipelines, the ITP concurs that the QuAD methodology (as described in proposed Appendix H to the Consent Decree) will provide a reliable basis for: (i) identifying intersecting dent-and-Corrosion features that present a sufficient threat of a pipeline rupture or leak to require designation as Features Requiring Excavation, and (ii) determining the Predicted Burst Pressure of intersecting dent-and-Corrosion features and establishing appropriate pressure restrictions for such features pending excavation and repair or mitigation of such features.

WHEREAS, the Parties have agreed to clarify application of requirements of the Consent Decree that provide for timely identification of Priority Features, particularly with respect to a category of Geometric features referred to as "ovalities."

WHEREAS, the Parties agree that the Fifth Modification of Consent Decree includes material changes that are subject to approval by the Court in accordance with Paragraph 201 of the Consent Decree.

WHEREAS, the Fifth Modification of Consent Decree will be lodged with the Court for a period of not less than 30 days for public notice and comment in accordance with 28 C.F.R. § 50.7. The United States reserves the right to withdraw from or withhold its consent if the comments regarding this Fifth Modification of Consent Decree disclose facts or considerations indicating that the Fifth Modification of Consent Decree is inappropriate, improper, or inadequate. Enbridge consents to the entry of this Fifth Modification of Consent Decree without further notice and agrees not to withdraw from or oppose entry of this Fifth Modification of Consent Decree by the Court or challenge any provision of the Fifth Modification of Consent

Decree, unless the United States has notified Enbridge in writing that it no longer supports entry of the Fifth Modification of Consent Decree.

WHEREAS, the Parties recognize, and the Court by entering this Fifth Modification of Consent Decree finds, that this Fifth Modification of Consent Decree has been negotiated at arm's length and in good faith, and that this Fifth Modification of Consent Decree is fair, reasonable, and in the public interest.

NOW THEREFORE, before taking any further testimony, without further adjudication of any issue of fact or law, and upon the consent and agreement of the Parties, it is hereby ORDERED, ADJUDGED, and DECREED as follows:

1. **Paragraph 10.s of the Consent Decree is modified to read as follows:**

s. "Established Maximum Operating Pressure" or "Established MOP" or "MOP" shall mean, with respect to each Lakehead System Pipeline segment, the MOP value listed for that segment in column C of the spreadsheet located at https://www.epa.gov/enbridge-spill-michigan/enbridge-revised-maximum-operating-pressure-values, except that the MOP values applicable to segments of Line 61 shall be the revised MOP values listed in column C of the spreadsheet located at https://www.epa.gov/enbridge-spill-michigan/enbridge-line-61-revised-maximum-operating-pressure. For purposes of identifying the MOP value applicable to any particular pipeline segment, pipeline segments are identified (in column B of the above-cited spreadsheet) by the milepost location at the beginning of the segment, and each pipeline segment includes the entire distance between the listed milepost location and the milepost location listed for the next pipeline segment identified on the spreadsheet.

2. **Paragraph 10.w of the Consent Decree is modified to read as follows:**

w. "Geometric feature" shall mean any feature that involves deformation of the pipe as defined in 4.28 of API Standard 1163 (1st Edition), including any bend, buckle, dent, ovality, ripple, wrinkle, or other change that affects the roundness of the pipe's cross section or straightness of the pipe. For purposes of this Consent Decree, the term "dent" shall refer to a local change in piping surface contour caused by an external force such as mechanical impact or rock impact, regardless of depth of the feature.

3. **Paragraph 19 of the Consent Decree is modified to read as follows:**

19. Enbridge shall fund and perform all injunctive measures set forth in Section VII as detailed in Subsections VII.A-J below and in Appendices A to H, which are incorporated into Section VII.

4. **Paragraph 32.c of the Consent Decree is modified to read as follows:**

c. In the case of ILI tools used to assess Geometric features, Initial ILI Reports shall be submitted to Enbridge:

(1) within 60 Days after the tool is removed from the pipeline at the conclusion of the inspection, in the case of each inspection completed prior to March 31, 2019; and

(2) within 90 Days after the tool is removed from the pipeline at the conclusion of the inspection, in the case of each inspection completed on or after March 31, 2019.

5. **The final sentence of Paragraph 33.b of the Consent Decree is modified to read as follows:**

b. * * *. At a minimum, Priority Features shall include each feature that meets any of the criteria set forth in Appendix A.

6. **The Table in Paragraph 37 of the Consent Decree is modified to read as follows:**

METHOD OF IDENTIFYING FEATURES REQUIRING EXCAVATION	APPLICABLE DEADLINES FOR IDENTIFYING FEATURES REQUIRING EXCAVATION AND PLACING SUCH FEATURES ON THE DIG LIST
Features that are identified as Features Requiring Excavation based upon their Predicted Burst Pressure	Enbridge shall complete identification of all such Features Requiring Excavation and add such features to the Dig List within five Days of calculating the Predicted Burst Pressure of the features in accordance with Subsection VII.D.(IV), below.
Features that are identified as Features Requiring Excavation based upon their Remaining Life	Enbridge shall complete identification of all such Features Requiring Excavation and add such features to the Dig List within five Days of calculating the Remaining Life of the features in accordance with Subsection VII.D.(VI) below.
Features, excluding dent features subject to Table 5, that are identified as Features Requiring Excavation based upon reasons other than their Predicted Burst Pressure or their Remaining Life	Enbridge shall complete identification of all such Features Requiring Excavation and add such features to the Dig List within 5 Days of completing the preliminary review of the Initial ILI Report, provided that such a review does not identify any data quality concerns relating to the feature. For those features with data quality concerns, Enbridge shall complete identification of all Features Requiring Excavation and add such features to the Dig List within 5 Days after resolving those data quality concerns.
Dent features subject to Table 5	Enbridge shall complete the identification of all such Features Requiring Excavation and add such features to the Dig List in accordance with the requirements of Paragraph 58.

7. **Paragraph 42.d of the Consent Decree is modified to read as follows:**

d. Crack or Corrosion features within dents; provided, however, that in any case where Enbridge elects to perform an evaluation of dents that intersect with Corrosion features in accordance with Subparagraph 58.c of the Consent Decree and Appendix H, Enbridge shall calculate the Predicted Burst Pressure of the Corrosion feature within the dent in the manner specified in Appendix H.

8. **Table 4 of the Consent Decree is modified so that the final row of the Table reads as follows:**

Table 4 – Criteria and Timelines for Excavation and Repair of Dents and Other Geometric Features		
Category	**Maximum time from date that feature is placed on the Dig List until date that feature is repaired/mitigated**	
	HCAs	**Non-HCAs**
* * *		
Any dent that (i) is located on a portion of Line 61 located outside of an HCA, (ii) has a depth greater than or equal to 2% of the nominal diameter of the pipe, (iii) affects the pipe curvature at a girth weld or a longitudinal weld, <u>and</u> (iv) has a remaining life that is less than 2 times the planned reinspection interval. For purposes of this provision, Enbridge shall determine the remaining life of each dent that meets the criteria in (i) – (iii) based on a fatigue assessment using a Finite Element Analysis (FEA) approach utilizing the ABAQUS or ANSYS FEA models.	N/A	365 Days

9. **Paragraph 58 of the Consent Decree is modified to read as follows:**

58. Dig-Selection Criteria for Intersecting or Interacting Features. Following each ILI Tool Run conducted on any Lakehead System pipeline segment on or after May 23, 2017, Enbridge shall identify each instance in which a detected feature satisfies one or more of the dig selection criteria in Table 5 below. Enbridge shall excavate and repair or mitigate each Unmitigated Intersecting Feature (as defined in Subparagraph 58.a.(1) of this Consent Decree) that meets one or more of the dig selection criteria in Table 5, and Enbridge shall establish pressure restrictions applicable to such features, as provided in Paragraph 59 of the Consent Decree.

a. General Requirements Applicable to Identification of Intersecting or Interacting Features That May be Subject to Dig Selection Criteria. As part of the process of identifying features that may be subject to the dig selection criteria in Table 5, Enbridge shall identify each instance in which a feature detected during an ILI Tool Run on or after May 23, 2017, intersects or interacts with any feature of a different type that was: (i) detected during the most recent previous ILI Tool Run conducted to detect such other feature type (including, if applicable, an ILI Tool Run completed prior to May 23, 2017), but (ii) not repaired or mitigated (*e.g.*, dents that intersect with a Crack feature, Corrosion feature, other metal loss feature, or stress riser; Crack features that intersect or interact with a Corrosion feature).

(1) To identify whether a feature detected in any ILI Tool Run on or after May 23, 2017, intersects or interacts with an unrepaired or unmitigated feature of a different type, Enbridge shall review the feature integration database required under Paragraph 74 of the Consent Decree and complete any additional review or analysis necessary to identify all intersecting or interacting features that have not previously been

repaired or mitigated ("Unmitigated Intersecting Features"), including any re-analysis of ILI data required under Subparagraph 58.b.(2) of the Consent Decree.

(2) Following each ILI Tool Run initiated on or after May 23, 2017, Enbridge shall complete the required identification of Unmitigated Intersecting Features within 30 Days after receipt of the Initial ILI Report, except as provided below in Subparagraph 58.b of the Consent Decree.

b. Additional Requirements Applicable to Identification of Dents that Intersect with Other Features.

(1) Enbridge shall require all Initial ILI Reports of geometry ILI Tool Runs initiated on or after March 31, 2019 to report all detected dents with depths that are greater than or equal to the geometry ILI tool vendor's published specification of the lower limit of detection for the ILI tool used ("Geometry Tool Reporting Standard").

(2) In the case of each Lakehead System pipeline segment where Enbridge initiated any ILI Tool Run from May 23, 2017 through March 30, 2019, inclusive, Enbridge shall:

(A) no later than December 15, 2019, complete a re-analysis of the geometry tool ILI data on such pipeline segment and identify all dents on such pipeline segment with depths that are (i) greater than or equal to the Geometry Tool Reporting Standard referred to above and (ii) less than 2% of the outer diameter of the pipeline; and

(B) no later than 60 Days after receiving the results of the required re-analysis of geometry tool ILI data relating to any such Lakehead System pipeline segment, identify all instances in which such unmitigated dents intersect with

unmitigated or unrepaired Crack features, Corrosion features or other metal loss features on such pipeline segment.

(3) In the case of each crack Tool Run and each metal loss Tool Run initiated on any Lakehead System pipeline segment on or after March 31, 2019, Enbridge shall identify whether detected Crack features, Corrosion features, other metal loss features or stress risers intersect with any detected dents that have depths that are greater than or equal to the Geometry Tool Reporting Standard referred to above.

(A) To the extent that geometry tool ILI data consistent with the Geometry Tool Reporting Standard is available for the relevant pipeline segment at the time Enbridge receives the Initial ILI Report for any crack ILI Tool Run or metal loss ILI Tool Run subject to this subparagraph, Enbridge shall complete such identification regarding intersecting features within the 30 Day timeframe specified in Subparagraph 58.a.(2) of the Consent Decree.

(B) To the extent that geometry tool ILI data consistent with the Geometry Tool Reporting Standard is not available for the relevant pipeline segment at the time Enbridge receives the Initial ILI Report for any crack Tool Run or metal loss Tool Run subject to this subparagraph, Enbridge shall, no later than 90 Days after receipt of such Initial ILI Report:

(i) complete a re-analysis of the geometry tool ILI data on such pipeline segment and identify all dents on such pipeline segment with depths that are (a) greater than or equal to the Geometry Tool Reporting Standard referred to above and (b) less than 2% of the outer diameter of the pipeline; and

(ii) identify all instances in which such dents intersect with Crack features, Corrosion features or other metal loss features on such pipeline segment.

c. Identification of Features Requiring Excavation. For each Unmitigated Intersecting Feature identified on any Lakehead System pipeline segment following any ILI Tool Run, Enbridge shall complete all evaluations and analysis necessary to determine whether such Unmitigated Intersecting Feature is a Feature Requiring Excavation, including, as applicable, the evaluations described below in Subparagraph 58.c.(3) of this Consent Decree.

(1) In the case of each Unmitigated Intersecting Feature, other than a dent detected by a geometry tool that has any indication of corrosion detected by a metal loss tool ("Unmitigated Dent/Corrosion Feature"), Enbridge shall (a) determine whether such feature satisfies one or more criteria in Table 5 within 30 Days after Enbridge's receipt of the Initial ILI Report that triggered Enbridge's obligation to identify and evaluate intersecting features, and (b) add each such feature to the Dig List within 5 Days of determining that the feature satisfies one or more criteria in Table 5.

(2) Following receipt of each Initial ILI Report relating to any ILI Tool Run conducted to detect, characterize and size Geometry Features or Corrosion Features on any Lakehead System pipeline segment(s), Enbridge shall identify all Unmitigated Dent/Corrosion Features on such pipeline segment(s) that meet criterion 2 or criterion 4 in Table 5, in accordance with the timeframes specified in Subparagraph 58.c.(2)(A) or (B) of the Consent Decree.

(A) Except as provided in Subparagraph 58.c.(2)(B) of the Consent Decree, within 35 Days after Enbridge's receipt of any Initial ILI Report relating

to any ILI Tool Run conducted to detect, characterize and size Geometry Features or Corrosion Features on any Lakehead System pipeline segment(s), Enbridge shall: (i) evaluate all Unmitigated Dent/Corrosion Features on such pipeline segment(s) in accordance with Subparagraph 58.c.(3)(A) and/or (B) of the Consent Decree, and (ii) identify all Unmitigated Dent/Corrosion Features on such pipeline segment(s) that satisfy criterion 2 or criterion 4 in Table 5 and add such features to the Dig List. In each instance in which Enbridge completes its evaluation of any Unmitigated Dent/Corrosion Feature in less than 30 days after receipt of the Initial ILI Report and determines that such feature satisfies criterion 2 or criterion 4 of Table 5, Enbridge shall add such feature to the Dig List within 5 Days after determining that the feature satisfies the applicable criterion.

(B) In any case where data consistent with the Geometry Tool Reporting Standard were not available with respect to Geometry Features on Lakehead System pipeline segment(s) at the time Enbridge received any Initial ILI Report relating to any ILI Tool Run conducted to detect, characterize and size Geometry Features or Corrosion Features on such pipeline segment(s), Enbridge shall: (i) complete its evaluation of all Unmitigated Dent/Corrosion Features on the relevant pipeline segment(s) in accordance with Subparagraph 58.c.(3)(A) and/or (B) of the Consent Decree, and (ii) identify all such features that satisfy criterion 2 or criterion 4 in Table 5. Enbridge shall add each such identified feature to the Dig List within 5 Days after completing its evaluation in accordance with Subparagraph 58.c.(3)(A) and/or (B) of the Consent Decree, but in no event later than 5 Days after the applicable deadline for

completing evaluation of such feature under Subparagraph 58.c.(3)(C)(ii) of the Consent Decree, below.

(3) Evaluation of Unmitigated Dent/Corrosion Features to Identify Features Requiring Excavation. In the case of each Unmitigated Dent/Corrosion Feature, Enbridge shall, at a minimum, complete the evaluation described in Subparagraph 58.c.(3)(A) of the Consent Decree, below, following each geometry ILI Tool Run and each metal loss ILI Tool Run, regardless of whether Enbridge completed such an evaluation following prior ILI Tool Runs.

(A) Enbridge shall complete a screening level evaluation of each Unmitigated Dent/Corrosion Feature identified on any Lakehead System pipeline segment using the Semi-Quantitative Analysis of Dents method ("SQuAD"). This evaluation shall be performed consistent with the requirements set forth in Appendix G and the deadlines set forth below in Subparagraph 58.c.(3)(C) of the Consent Decree. As part of this screening level evaluation for each Unmitigated Dent/Corrosion Feature, Enbridge shall determine the ratio of the calculated strain capacity of the feature to the maximum operational strain demand of the feature (hereinafter referred to as the "strain safety factor"), and Enbridge shall identify all such features with a strain safety factor of less than 2.0.

(B) In addition to completing SQuAD evaluations pursuant to Subparagraph 58.c.(3)(A) of the Consent Decree, Enbridge may perform a more refined evaluation of any Unmitigated Dent/Corrosion Feature using the Quantitative Analysis of Dents method ("QuAD"), consistent with the requirements specified in Appendix H. As part of each QuAD evaluation of an Unmitigated Dent/Corrosion Feature, Enbridge shall

demonstrate whether the evaluated feature: (i) has a strain safety factor greater than or equal to 1.25, (ii) has a Predicted Burst Pressure that is greater than or equal to 1.39 times the Established MOP at the location of the feature, and (iii) has a fatigue life that is at least four (4) times the planned reinspection interval established consistent with the requirements of this Consent Decree. If Enbridge demonstrates, based on a QuAD evaluation, that any Unmitigated Dent/Corrosion Features satisfies all of the criteria set forth in (i) through (iii) of this Subparagraph 58.c.(3)(B) of the Consent Decree, such feature shall not be considered a Feature Requiring Excavation, regardless of the results of the SQuAD evaluation required above. If Enbridge demonstrates that any feature previously added to the Dig List pursuant to Subparagraph 58.c.(1) or (2) of the Consent Decree , above, satisfies all of the criteria set forth in (i) through (iii) of this Subparagraph 58.c.(3)(B) of the Consent Decree, Enbridge may remove such feature from the Dig List and adjust or remove the pressure restriction to the extent consistent with Paragraph 59 of the Consent Decree.

(C) Deadlines For Completing Evaluation of Features Using SQuAD and QuAD.

(i) Except as provided below in this Subparagraph 58.c.(3)(C) of the Consent Decree, Enbridge shall complete all evaluations of each Unmitigated Dent/Corrosion Feature pursuant to Subparagraph 58.c.(3)(A) and (B) of the Consent Decree within 35 Days after receipt of the Initial ILI Report that triggered Enbridge's obligation to identify intersecting features under this Paragraph 58. Nothing in this Subparagraph 58.c.(3)(C)(i) of the Consent Decree shall be construed to alter or

extend the deadlines in Subparagraph 58.c.(2)(A) of the Consent Decree for placing any Unmitigated Dent/Corrosion Features on the Dig List.

(ii) With respect to each Unmitigated Dent/Corrosion Feature identified based on a re-analysis of geometry ILI tool data pursuant to Subparagraph 58.b.(2) of the Consent Decree or pursuant to Subparagraph 58.b.(3)(B) of the Consent Decree, above, Enbridge shall complete all evaluations of each Unmitigated Dent/Corrosion Feature using the SQuAD evaluation required under Subparagraph 58.c.(3)(A) of the Consent Decree , as well as any additional QuAD evaluations performed pursuant to Subparagraph 58.c.(3)(B) of the Consent Decree, above, with respect to such Unmitigated Dent/Corrosion Feature, within 60 Days after identification of such Unmitigated Dent/Corrosion Feature.

(iii) The failure to complete a QuAD evaluation of any Unmitigated Dent/Corrosion Feature within the applicable time frame specified in Subparagraph 58.c.(3)(C)(i) or (ii) of the Consent Decree, above, shall not extend the applicable deadline under Subparagraph 58.c.(2)(A) or (B) of the Consent Decree to add such feature to the Dig List based on a SQuAD evaluation of such feature, but such failure shall not be considered a violation of the Consent Decree that is subject to assessment of stipulated penalties under Section XI of this Decree.

(iv) Nothing in this Subparagraph 58.c.(3)(C) shall be construed to preclude Enbridge from continuing or completing a QuAD evaluation of any Unmitigated Dent/Corrosion Feature after the applicable deadlines in Subparagraph 58.c.(3)(C)(i) or (ii) of the Consent Decree. If a QuAD evaluation of any Unmitigated Dent/Corrosion Feature previously added to the Dig List demonstrates that such feature

satisfies all of the criteria established in Subparagraph 58.c.(3)(B)(i)-(iii) of the Consent Decree , then Enbridge may remove such feature from the Dig List. In addition, if Enbridge completes a QuAD evaluation of any Unmitigated Dent/Corrosion Feature after the applicable deadlines in Subparagraph 58.c.(3)(C)(i) or (ii) of the Consent Decree, such QuAD evaluation may be used to revise any pressure restriction previously established for such feature, to the extent authorized in Paragraph 59.c of the Consent Decree.

(D) Information Requirements.

(i) For each SQuAD evaluation performed pursuant to this Consent Decree, Enbridge shall, upon request, promptly provide to the ITP all data, information, and software (including any updates) required to replicate the SQuAD analysis, including, as a minimum, all dent inputs, all dent outputs, and a report summarizing the results and highlighting any features for which the Safety Factor is determined to be less than 2.0.

(ii) For each QuAD evaluation performed pursuant to this Consent Decree, Enbridge shall, upon request, promptly provide to the ITP a report that contains, as a minimum, the inputs used in the analysis, threat integration details for the features being analyzed, details of the feature profile matching, any case-specific assumptions, and the results of the strain, fatigue, and burst pressure analyses, along with any conclusions drawn and the ultimate disposition of each such feature.

d. Nothing in this Paragraph 58 of the Consent Decree shall be construed to modify the provisions of Paragraph 34 of this Consent Decree (Data Quality Review).

Table 5 – Criteria and Timelines for Excavation and Repair of Intersecting or Interacting Feature Types			
Criterion No.	**Dig Selection Criteria**	**Maximum time from date that feature is placed on the Dig List until date that feature is repaired/mitigated**	
		High Consequence Area ("HCA")	**Non-HCA**
1	Any dent located in the top of the pipeline (above the 4 and 8 o'clock positions) that has any indication of cracking, metal loss other than corrosion, or a stress riser.	As expeditiously as practicable, but not to exceed 30 Days	As expeditiously as practicable, but not to exceed 60 Days for each dent deeper than 2% of the outer diameter of the pipeline; otherwise, excavate and repair within 365 Days
2	Any dent located on the top of the pipeline (above the 4 and 8 o'clock positions) that has any indication of corrosion and has a strain safety factor less than 2.0, determined in accordance with Appendix G, unless Enbridge demonstrates that the feature satisfies all of the criteria in Paragraph 58.c.(3)(B) of the Consent Decree, above.	As expeditiously as practicable, but not to exceed 30 Days	As expeditiously as practicable but not to exceed 60 Days
3	Any dent located in the bottom of the pipeline (below the 4 and 8 o'clock positions) that has any indication of cracking, metal loss other than corrosion, or a stress riser.	Not to exceed 60 Days	180 Days for a dent deeper than 2% of the outer diameter of the pipeline; otherwise, excavate and repair within 365 Days

Table 5 – Criteria and Timelines for Excavation and Repair of Intersecting or Interacting Feature Types			
Criterion No.	**Dig Selection Criteria**	**Maximum time from date that feature is placed on the Dig List until date that feature is repaired/mitigated**	
		High Consequence Area ("HCA")	**Non-HCA**
4	Any dent located on the bottom of the pipeline (below the 4 and 8 o'clock positions) that has any indication of corrosion and has a strain safety factor less than 2.0, determined in accordance with Appendix G, unless Enbridge demonstrates that the feature satisfies all of the criteria in Paragraph 58.c.(3)(B) of the Consent Decree, above.	Not to exceed 60 Days	Not to exceed 180 Days
5	Any case in which a Crack feature intersects or interacts with a Corrosion feature and the Predicted Burst Pressure of such interacting or intersecting features determined using the CorLAS™ model (assessed as a Crack-like feature) is less than 1.25 x the Established MOP.	Not to exceed 180 Days, except as provided in Paragraph 49 of the Consent Decree	Not to exceed 180 Days except as provided in Paragraph 49 of the Consent Decree

Table 5 – Criteria and Timelines for Excavation and Repair of Intersecting or Interacting Feature Types			
Criterion No.	**Dig Selection Criteria**	**Maximum time from date that feature is placed on the Dig List until date that feature is repaired/mitigated**	
		High Consequence Area ("HCA")	**Non-HCA**
6	Any intersecting or interacting Crack/Corrosion feature with a Remaining Life (determined in accordance with Subsection VII.D.(VI), below) that is less than 5 years (i.e., a feature that is predicted to grow, within five years or less, to a point where its Predicted Burst Pressure will be less than the Established MOP).	365 Days, except that if the Remaining Life of the feature is ≤ 365 Days from the time the feature was added to the Dig List, then repair/mitigation shall be as expeditiously as practicable, and in no event longer than 30 Days	365 Days, except that if the Remaining Life of the feature is ≤ 365 Days from the time the feature was added to the Dig List, then repair/mitigation shall be as expeditiously as practicable, and in no event longer than 30 Days
7	Any intersecting or interacting Crack/Corrosion feature with a Remaining Life that is less than 2 x the planned re-inspection interval.	365 Days, except that if the Remaining Life of the feature is ≤ 365 Days from the time the feature was added to the Dig List, then repair/mitigation shall be as expeditiously as practicable, and in no event longer than 30 Days	365 Days, except that if the Remaining Life of the feature is ≤ 365 Days from the time the feature was added to the Dig List, then repair/mitigation shall be as expeditiously as practicable, and in no event longer than 30 Days

10. **Paragraph 59 of the Consent Decree is modified to read as follows:**

59. Enbridge shall establish a pressure restriction for Unmitigated Intersecting Features listed in Table 5, as provided below in this Paragraph 59 of the Consent Decree, and Enbridge shall maintain each such pressure restriction until such time as the feature has been excavated and repaired or mitigated.

a. Within 2 Days after determining that any unmitigated intersecting or interacting Crack/Corrosion feature has a Predicted Burst Pressure that is less than 1.25 times the Established MOP, Enbridge shall limit operating pressure at the location of the feature to not more than 80% of the Predicted Burst Pressure.

b. Within 2 Days after determining that any dent has the characteristics specified in either Criterion 1 or Criterion 3 of Table 5, Enbridge shall limit operating pressure at the location of such feature to not more than 80% of the highest actual operating pressure at the location of such feature over the last 60 days.

c. In the case of each Unmitigated Dent/Corrosion Feature that has the characteristics specified in either Criterion 2 or Criterion 4 of Table 5, Enbridge shall limit the operating pressure at the location of the feature as specified below in this Subparagraph 59.c. of the Consent Decree.

(1) Within 2 Days after determining that any Unmitigated Dent/Corrosion Feature has the characteristics specified in either Criterion 2 or Criterion 4 of Table 5, based on its evaluation of such feature pursuant to Subparagraph 58.c.(3)(A) and/or (B) of the Consent Decree, but in no event later than 2 Days after the applicable deadline for completing evaluation of such feature under Subparagraph 58.c.(3)(C)(i), (ii)

or (iii) of the Consent Decree, above, Enbridge shall limit operating pressure at the location of such feature to not more than 80% of the highest actual operating pressure at the location of such feature over the last 60 days, *unless*, prior to the deadline for implementing such pressure restriction, Enbridge has either:

(A) demonstrated that that all criteria for removing the feature from the Dig List under Subparagraph 58.c.(3)(B) of the Consent Decree are satisfied, in which case no pressure restriction shall be required at the location of the feature, or

(B) determined a Predicted Burst Pressure of the Feature in accordance with the QuAD methodology in Appendix H, in which case Enbridge shall limit operating pressure at the location of the feature to the Predicted Burst Pressure of the feature ÷ 1.39.

(2) In any case where Enbridge does not complete a QuAD evaluation of any such Unmitigated Dent/Corrosion Feature until after a pressure restriction has been established in accordance with Paragraph 59.c.(1) of the Consent Decree, above, Enbridge may:

(A) Remove the pressure restriction at the location of such feature if the subsequently completed QuAD evaluation demonstrates that the feature satisfies all of the criteria specified in Subparagraph 58.c.(3)(B) of the Consent Decree for removing such feature from the Dig List; or

(B) Limit the operating pressure at the location of the feature to the Predicted Burst Pressure of the feature ÷ 1.39, where the Predicted Burst Pressure of the feature was determined in accordance with the QuAD methodology in Appendix H.

11. **Paragraph 61.a of the Consent Decree is modified to read as follows:**

61. Enbridge shall not be required to calculate the Remaining Life of:

a. any feature described in Subparagraphs 42.a – d of the Consent Decree;

provided, however, that in any case where Enbridge is not required to repair or permanently mitigate any intersecting dent-and-Corrosion feature based on an evaluation conducted pursuant to Appendix G or Appendix H, Enbridge shall calculate the Remaining Life of such corrosion feature in accordance with this Section VII.D.(VI) of the Consent Decree.

12. **Paragraph 212 of the Consent Decree is modified to add the following text at the end of the existing language:**

"Appendix G" is a description of the Method for the Evaluation of Intersecting Dents/Corrosion Features Using SQuAD.

"Appendix H" is a description of the Method for the Evaluation of Intersecting Dents/Corrosion Features Using QuAD.

13. **Appendix A is modified to read as follows:**

Technology	**Priority Feature Notification Criteria**
Line Proving & Geometry	1. Ovalities ≥ 10 % OD. 2. Dents and Geometric features (other than ovalities) ≥ 5% OD. 3. Priority notification criteria specifically identified in the project work order; provided that such criteria are not less stringent than the criteria listed above.

Technology	Priority Feature Notification Criteria
Corrosion Ultrasonics & Magnetic Flux Leakage	1. Metal loss features with peak depths ≥ 75% of Nominal Wall Thickness ("NWT"). 2. Metal loss feature with an effective area RPR ≤ 0.85. 3. Metal loss features forecasted to reach maximum depth ≥ 75%. NWT or actual wall thickness within 365 calendar days. 4. Unmatched metal loss features with a depth ≥ 50% NWT. 5. Unmatched metal loss features with a depth ≥50% actual wall thickness. 6. Priority notification criteria specifically identified in the project work order; provided that such criteria are not less stringent than the criteria listed above.
Crack Ultrasonics	1. Crack features that meet or exceed the saturation limit of the crack detection tool. 2. Crack features ≥ 2.5 mm (0.098 inch), and have been detected on the internal and external pipe surface at the same location. 3. Priority notification criteria specifically identified in the project work order.

14. This Fifth Modification of Consent Decree will be lodged with the Court for a period of not less than 30 days for public notice and comment in accordance with 28 C.F.R. § 50.7. The United States reserves the right to withdraw from or withhold its consent if the comments regarding this Fifth Modification of Consent Decree disclose facts or considerations indicating that the Fifth Modification of Consent Decree is inappropriate, improper, or inadequate. Enbridge consents to the entry of this Fifth Modification of Consent Decree without further notice and agrees not to withdraw from or oppose entry of this Fifth Modification of Consent Decree by the Court or challenge any provision of the Fifth Modification of Consent Decree, unless the United States has notified Enbridge in writing that it no longer supports entry of the Fifth Modification of Consent Decree.

15. If the Court does not approve this Fifth Modification of Consent Decree as submitted, the United States agrees that Enbridge's reliance on Paragraph 4 of this Fifth Modification of Consent Decree (that would establish a revised 90 Day deadline for receipt of Initial ILI Reports relating to certain geometry ILI Tool Runs) shall not constitute a violation of the Consent Decree with respect to any geometry ILI Tool Run conducted between March 31, 2019 and the time that either (i) the Court declines to approve this Fifth Modification of Consent Decree as submitted or (ii) the United States provides Enbridge with written notification that the United States has determined to withdraw or withhold its consent to the proposed Fifth Modification of Consent Decree. Following execution of this Fifth Modification of Consent Decree, the provisions of this Paragraph 15 of the Fifth Modification of Consent Decree shall survive and be enforceable even if the Fifth Modification of Consent Decree ultimately does not become effective.

16. The effective date of this Fifth Modification of Consent Decree shall be the date upon which the Fifth Modification of Consent Decree is entered by the Court following notice and comment in accordance with Paragraph 14 of this Fifth Modification of Consent Decree or a motion to enter the Fifth Modification of Consent Decree is granted, whichever occurs first, as recorded in the Court's docket; provided, however, that Enbridge hereby agrees that they shall be bound to perform duties scheduled to occur prior to the effective date of this Fifth Modification of Consent Decree. In the event that the United States withdraws from, or withholds its consent to, this Fifth Modification of Consent Decree, then the preceding requirement to perform duties scheduled to occur before the effective date of this Fifth Modification of Consent Decree shall terminate. Nothing in this Paragraph shall affect or limit application of any provisions of Paragraph 15 of this Fifth Modification of Consent Decree.

THE UNDERSIGNED PARTY enters into this Fifth Modification of Consent Decree in *United States v. Enbridge Energy, Limited Partnership, et al.*, Civil Action No. 1:16-cv-914 (W.D. MI).

FOR PLAINTIFF UNITED STATES OF AMERICA:

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THE UNDERSIGNED PARTY enters into this Fifth Modification of Consent Decree in *United States v. Enbridge Energy, Limited Partnership, et al.*, Civil Action No. 1:16-cv-914 (W.D. MI).

FOR PLAINTIFF UNITED STATES OF AMERICA (CONTINUED)

T. Leverett Nelson

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Date: 2020.05.06 16:09:03 -05'00'

T. LEVERETT NELSON
Regional Counsel
U.S. EPA, Region 5
Chicago, Illinois

THE UNDERSIGNED PARTY enters into this Fifth Modification of Consent Decree in *United States v. Enbridge Energy, Limited Partnership, et al.*, Civil Action No. 1:16-cv-914 (W.D. MI).

FOR PLAINTIFF UNITED STATES OF AMERICA (CONTINUED)

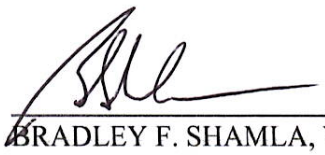
5-4-2020

MARK POLLINS
Director
Water Enforcement Division
Office of Civil Enforcement
Office of Enforcement and Compliance Assurance
U.S. Environmental Protection Agency

The undersigned party enters into and agrees to be bound by this Fifth Modification of Consent Decree in *United States v. Enbridge Energy, Limited Partnership, et al.*, 1:16-cv-914 (W.D. MI).

FOR DEFENDANTS:

ENBRIDGE ENERGY, LIMITED PARTNERSHIP,
ENBRIDGE PIPELINES (LAKEHEAD) L.L.C.,
ENBRIDGE ENERGY PARTNERS, L.P.,
ENBRIDGE ENERGY MANAGEMENT, L.L.C.,
ENBRIDGE ENERGY COMPANY, INC., and
ENBRIDGE EMPLOYEE SERVICES, INC.

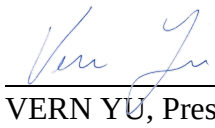


BRADLEY F. SHAMLA, Vice President, U.S. Operations

The undersigned party enters into and agrees to be bound by this Fifth Modification of Consent Decree in *United States v. Enbridge Energy, Limited Partnership, et al.*, 1:16-cv-914 (W.D. MI).

FOR DEFENDANTS:

ENBRIDGE OPERATIONAL SERVICES, INC.,
ENBRIDGE PIPELINES INC., and
ENBRIDGE EMPLOYEE SERVICES CANADA INC.



VERN YU, President

APPENDIX G

Appendix G

Analysis of Unmitigated Dents/Corrosion Features Using SQuAD

A. SQuAD Methodology

1. As provided in Paragraph 58 of the Consent Decree, Enbridge shall complete a screening level evaluation of each dent feature detected by a geometry ILI tool that intersects with a Corrosion feature detected by a metal loss ILI tool using a semi-quantitative analysis of dents method ("SQuAD"). Nothing in this Appendix G shall be construed to limit Enbridge's ability to perform an additional, more detailed analysis of any intersecting dent-and-Corrosion feature using a quantitative finite element analysis of dents method ("QuAD") in accordance with requirements set forth in Appendix H, or Enbridge's ability to use the results of any such QuAD analysis in any manner authorized in Subparagraph 58.c or 59.c.

2. SQuAD shall be used to complete a screening level evaluation of all dent features detected by geometry ILI tools that intersect with Corrosion features detected by metal loss tools. Using SQuAD, the mean value of the strain demand per feature is evaluated using ASME B31.8 standard analytical equations, as described below in Section B of this Appendix G. The strain demand variability (i.e. statistical distribution) is evaluated as described below in Paragraph B.2 by considering geometry ILI measurements error based on the vendor's specifications and pipe properties uncertainties as shown in Table 1. The mean value and variability (i.e. statistical distribution) of the strain capacity of the pipe at the location of the feature being evaluated are estimated based on steel pipe properties based on API 5L and CSA Z662 Annex O. The strain capacity statistical distribution shall be penalized by all applicable "m" multipliers listed in Table 2 in order to de-rate the strain capacity based on additional, potentially injurious factors, such as intersection with corrosion, complex dent shapes, and severity of pressure cycling.

Table 1 Key Input Basic Random Variables

Variable	Unit	Distribution	Uncertainty	Comments
Diameter	mm	Normal	CoV = 0.2%	CoV = coefficient of variation
Wall Thickness	mm	Normal	CoV = 2.4%	
Dent Depth	mm	Normal	Varies per Geometry tool*	
Dent Length (longitudinal)	mm	Normal	Varies per Geometry tool*	
Dent Width (circumferential)	mm	Normal	Varies per Geometry tool*	¼ of the Center to Center Spacing from the Geometry ILI Specification*

** As defined by vendor's specifications*

Table 2 "m" Multipliers used in SQuAD

Multiplier	Distribution	Minimum	Maximum
Topside Dent	Uniform	0.70	0.90
Multi-Apex Dent	Uniform	0.80	0.95
Dent in Close Proximity to another Dent	Uniform	0.75	0.95
Dent Associated with Weld	Uniform	0.80	0.95
Off-Axis Dent	Uniform	0.80	0.95
Dent with Corrosion	Uniform	0.60	0.95
Light Pressure Cycling	Uniform	0.98	1.00
Moderate Pressure Cycling	Uniform	0.90	0.98
Aggressive Pressure Cycling	Uniform	0.80	0.95

3. In using SQuAD, Enbridge shall simulate strain demand and strain capacity distributions as per Section B and Section C in this Appendix G; respectively.

4. Enbridge shall determine the SQuAD strain safety factor of each intersecting dent and-Corrosion feature as provided in Section D of this Appendix G.

B. Calculating Strain Demand

For dent features intersecting with corrosion, Enbridge shall determine the strain demand for each dent feature detected by a geometry ILI tool using ASME B31.8 Appendix R, which is a function of the dent feature properties and radii of curvature values from the ILI-measured profile. The ILI profile inherently accounts for ovality effects.

B.1 Strain Demand Equations

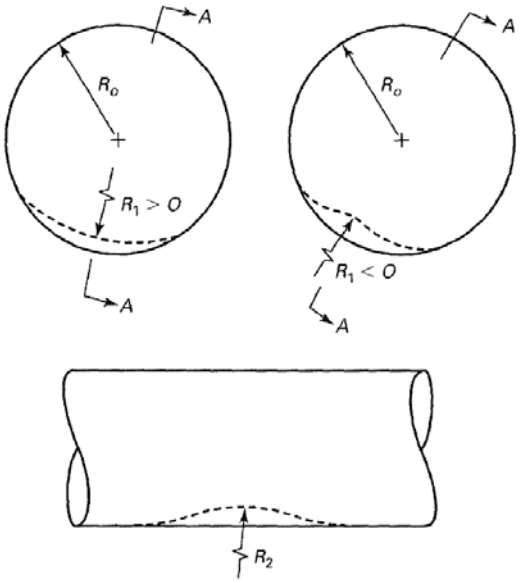
1. Enbridge shall use the strain equations provided in ASME B31.8 Appendix R to calculate the strain within a dent feature as follows:

$$\varepsilon_1 = \frac{t}{2}\left(\frac{1}{R_o} - \frac{1}{R_1}\right) \quad (1)$$

$$\varepsilon_2 = -\frac{t}{2R_2} \quad (2)$$

$$\varepsilon_3 = \frac{1}{2}\left(\frac{d}{L}\right)^2 \quad (3)$$

where, ε_1 represents the circumferential bending strain, ε_2 the longitudinal bending strain, and ε_3 the longitudinal membrane strain. The radii of curvature values R_o, R_1, and R_2 are shown graphically in Figure 1. The terms t, d and L represent the pipe wall thickness, dent depth and longitudinal dent



length; respectively.

Figure 1 Radius of Curvature Measurement Requirements

2. Enbridge shall use the location and depth of the most severe point (MSP) and the points where the dent depth is one-half of the MSP depth (i.e. the half-peak) based on the geometry ILI tool report. This information shall be used to approximate the radius of curvature at the dent's apex through fitting a three-point circle through the available points as shown in Figure 2. Enbridge shall use this methodology in both the longitudinal and circumferential directions to calculate R_1 and R_2 (radii of curvatures).

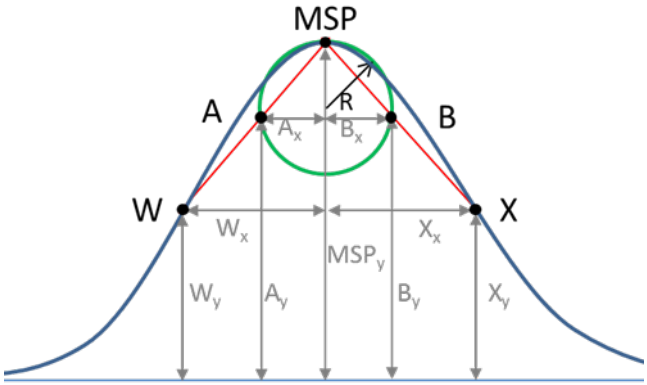


Figure 2 Radius of Curvature using MSP and Half-Peak Values (W and X)

3. Equations (1) to (3) shall be used to calculate the maximum expected strain on the internal (ε_i) and external (ε_o) surfaces of the pipe as shown Equations (4) and (5). The maximum of ε_i and ε_o is the peak strain within the dent feature.

$$\varepsilon_i = \sqrt{\varepsilon_1^2 - \varepsilon_1(\varepsilon_2 + \varepsilon_3) + (\varepsilon_2 + \varepsilon_3)^2} \quad (4)$$

$$\varepsilon_o = \sqrt{\varepsilon_1^2 + \varepsilon_1(-\varepsilon_2 + \varepsilon_3) + (-\varepsilon_2 + \varepsilon_3)^2} \quad (5)$$

B.2 Determining Strain Demand Statistical Distribution

1. Enbridge shall use the uncertainties associated with pipe properties, dent depth, dent length, and dent width as per Table 1 in evaluating Equations (1) to (5) per feature. Enbridge shall use Monte Carlo simulation method to simulate the strain demand distribution per feature.

2. Enbridge shall use classical statistical methods to estimate the strain demand statistical parameters (mean and standard deviation) and fit the strain demand histogram per feature to common engineering statistical distributions (e.g. Normal, Lognormal, Exponential, or Weibull) as per ISO 16708 Section A3.3.

3. Enbridge shall verify the adequacy of the fitted strain demand statistical distribution per feature by statistical tests and the probability paper method as per ISO 16708 Section A3.3.

C Calculating Strain Capacity

1. Enbridge shall model the strain capacity of 30% with a Normal distribution and a coefficient of variation of 6% based on API 5L and CSA Z662 Annex O recommendations.

2. For each dent detected by a geometry ILI tool that intersects with a Corrosion feature detected by a metal loss tool, Enbridge shall multiply the strain capacity distribution for such dent by all applicable penalty "m" multipliers, listed in Table 2.

C.1 Determining Strain Capacity Statistical Distribution

1. Enbridge shall use Monte Carlo Simulation method to simulate the strain capacity distribution multiplied by the related "m" factors per feature based on the uncertainties associated with strain capacity and "m" multipliers (listed in Table 2) variabilities.

2. Enbridge shall use classical statistical methods to estimate strain capacity distribution parameters and fit the strain capacity histogram per feature to common engineering statistical distributions (e.g. Normal, Lognormal, Exponential, or Weibull) as per ISO 16708 Section A3.3.

3. Enbridge shall verify the adequacy of the fitted strain capacity statistical distribution per feature by statistical methods and the probability paper as per ISO 16708 Section A3.3.

D. Establish SQuAD Strain Safety Factor

1. For each dent detected by a geometry ILI tool that intersects with a Corrosion feature, Enbridge shall calculate SQuAD strain safety factor (γ) by dividing the strain capacity characteristic value (C_c) (5^{th} percentile of strain capacity distribution) by the strain demand characteristic value (D_c) (95^{th} percentile of the strain demand distribution) as shown in Equation (6).

$$\gamma = \frac{C_c}{D_c} \qquad (6)$$

E. Identification of Features Requiring Excavation

If the SQuAD strain safety factor (γ) of any feature is less than a safety factor threshold of 2.0, Enbridge may conduct a further analysis of such feature using the Quantitative Analysis of Dents (QuAD) methodology described in Appendix H of the Consent Decree; provided, however, that

notwithstanding the initiation of any QuAD analysis, Enbridge shall comply with all applicable provisions of Paragraphs 58 and 59 of the Consent Decree that (1) establish deadlines for identifying Features Requiring Excavation and adding such features to the Dig List; and (2) provide for imposition of pressure restrictions at the location of features on the Dig List.

APPENDIX H

Appendix H
Detailed Analysis of Unmitigated Dent/Corrosion Features Using QuAD

A. QuAD Methodology

1. Enbridge may use the Quantitative Analysis of Dents (QuAD) methodology described in this Appendix H to perform a more detailed quantitative analysis of any Unmitigated Dent/Corrosion Feature that was previously evaluated under Paragraph 58.b of the Consent Decree using the Semi-Quantitative Analysis of Dents (SQuAD) methodology.

2. QuAD is a finite element analysis (FEA) method combined with an analysis that accounts for uncertainties associated with pipe properties and In-Line Inspection (ILI) tool measurements. QuAD is used to evaluate strain, burst, and fatigue limit states of Unmitigated Dent/Corrosion Features and determine safety factors of such features.

3. Enbridge shall use the commercial software ABAQUS for FEA and modeling of the pipe, dents, and intersecting Corrosion features. The pipe steel material's nonlinear behavior shall be modelled with uniaxial stress strain curves corresponding to specific material grades as elastic-plastic materials. The input information required for the FEA model shall be the geometry of the dent as detected by the geometry ILI tool, Corrosion feature measurements as detected by the metal loss ILI tool, nominal pipe diameter, pipe wall thickness, pipe steel grade, maximum operating pressure, and operating pressure during the geometry ILI tool run.

4. The pipe geometry shall be modeled as a solid structure and discretized using three dimensional finite elements. The pipe wall thickness shall be discretized into a minimum of four layers, the first of which shall have a variable thickness equal to the depth of the Corrosion feature. A finite element mesh size ranging between 1.5 mm and 3.0 mm shall be used within the dent region, and Enbridge shall select mesh sizes that minimize the transition between areas with metal loss and areas with full wall thickness. The finer mesh is necessary within the dent region to account for the abrupt changes in the curvature of the pipe surface. The mesh size shall be allowed to increase up to 30 to 50 mm in regions away from the dent as deemed appropriate, provided that such increase in mesh size does not affect results within the dent feature.

5. For each Unmitigated Dent/Corrosion Feature evaluated using QuAD, the dent geometry profile shall be obtained from the geometry ILI tool raw data and shall reflect the depth of the dent as detected by the geometry ILI tool, regardless of any reporting specifications established by Enbridge at the time of the geometry ILI tool run. The most severe point (MSP) of the dent shall be identified. The longitudinal and circumferential cross sections of the dent profile through its MSP shall be extracted from the Geometry ILI data and shall be considered to represent the dent shape. Based on the longitudinal and circumferential profiles, an initial shape and size of indenter geometry shall be approximated. The indenter is an FEA modelling attribute used to establish dent geometry in the FEA environment and shall be modeled as a rigid body. The loads and displacements applied to the pipe and indenter shall be defined as follows:

- PMOP: Pressure on the internal pipe surface shall be equal to the Established Maximum Operating Pressure;
- PILI: Pressure on the internal pipe surface shall be equal to the operating pressure during geometry ILI tool run;
- D: Pipe shall be depressurized to zero internal pressure;
- I: Displacement shall be applied to the rigid indenter to create an indentation on the pipe;
- R: Displacement shall be applied to the rigid indenter to remove it from interacting with the pipe.

Specific sequences of these load steps shall be selected depending on whether the dent was formed during or after construction (based on reviewing the ILI history), and whether the dent is restrained or unrestrained (based on the shape and location of the dent). The FEA shall be performed using the appropriate loading sequence per dent feature.

6. The dent profile shall be extracted from FEA and compared to the geometry ILI tool profile of the same dent. For each Unmitigated Dent/Corrosion Feature evaluated in accordance with this Appendix H, Enbridge shall ensure that any differences between the FEA and ILI profiles of the dent are less than or equal to the geometry ILI tool vendor's depth accuracy specification in both longitudinal and circumferential directions. For purposes of this Appendix H, the FEA profile for a dent shall be deemed to be within an acceptable margin of error of the geometry ILI reported profile if a comparison of the FEA and geometry ILI tool profiles satisfy both of the following criteria:

- At least 95% of the FEA profiles over the full area of the dent may not differ from the corresponding points on the geometry tool ILI profiles by an amount that is greater than the ILI vendor's depth accuracy specification in either the longitudinal or the circumferential directions; and
- In any portions of the dent that have an abrupt curvature change such that the radius of curvature of the dent profile in any direction is less than or equal to five times the wall thickness, all corresponding data points on the FEA and geometry tool ILI profiles of the dent shall have equivalent values (*i.e.*, within areas of abrupt curvature change, no values may differ by an amount that is greater than the ILI vendor's depth accuracy specification in either the longitudinal or the circumferential directions).

7. The geometry of the metal loss feature shall be incorporated into the pipe geometry FEA model by cutting out a portion of the pipe wall elements. The dimensions of this cut-out corrosion geometry shall be determined by the dimensions of the Corrosion feature (effective depth, effective length and width) as reported by the corrosion ILI tool.

8. Strain Demand. The input variables to the FEA shall be modeled statistically as listed in Table 1. Enbridge shall utilize a design of experiment method to model the strain demand. Enbridge shall evaluate 2n+1 FEA iterations (where n is the number of variables listed in Table 1) to fit the strain demand FEA results (dependent variable) against the variables listed in Table 1 (independent variables) to a linear or polynomial function using regression analysis. Enbridge will cause the n variables (shown in Table 1) to be varied by at least two standard deviations above and

below the mean value to account for uncertainties in the variables and their influences on the resulting demand distribution. The choice of a linear or quadratic function shall be based on minimizing the squared errors between the FEA results and the regressed function and choosing the best fit function. The chosen regressed function shall represent the strain demand as a function of the variables listed in Table 1.

Table 1 Key Input Statistical Variables

Variable	Unit	Distribution	Mean	Uncertainty
Wall Thickness	mm	Normal	Nominal	CoV** = 2.4%
Yield Strength	MPa	Normal	1.1 × SMYS*	CoV** = 3.4%
Dent Depth	mm	Normal	As detected by geometry ILI tool	Tool tolerance as specified by ILI vendor
Corrosion Depth	mm	Normal	As reported by ILI tool	Depth tolerance as specified by ILI vendor
Corrosion Length	mm	Normal	As reported by ILI tool	Length tolerance as specified by ILI vendor

**SMYS is the specified minimum yield strength of the pipe material*
*** Coefficient of variation*

9. Enbridge shall use Monte Carlo simulation method to simulate the strain demand (dependent variable) statistical distribution based on the regressed function. Enbridge shall use the uncertainties associated with the variables listed in Table 1 (independent variables) for simulation purposes.

10. Enbridge shall use classical statistical methods to estimate the strain demand statistical parameters (mean and standard deviation) and fit the strain demand histogram to common engineering statistical distributions (e.g. Normal, Lognormal, Exponential, or Weibull) as per ISO 16708 Section A3.3.

11. Enbridge shall verify the adequacy of the fitted strain demand distribution by statistical tests and the probability paper method as per ISO 16708 Section A3.3.

12. Strain Capacity. Enbridge shall model the strain capacity of 30% with a Normal distribution and a coefficient of variation of 6% based on API 5L and CSA Z662 Annex O recommendations.

13. Burst Pressure Analysis. For burst pressure analysis of Unmitigated Dent/Corrosion Features, Enbridge shall utilize FEA to account for geometric nonlinearities such as the change in global stiffness of the dent and the bulging within a Corrosion feature due to applied internal pressure. During the FEA process for determining burst pressure, the dent shall

be modelled as unrestrained to allow for rebounding and re-rounding of the dented region and ensure a conservative estimate of the burst pressure. The input variables to the FEA shall be specified minimum yield strength, pipe outer diameter and nominal wall thickness, dent profile from geometry ILI tool, corrosion effective depth, corrosion effective length, and corrosion width as determined by the metal loss tool. Enbridge shall evaluate the average stresses within the Corrosion feature as a function of the internal pressure. The burst pressure (P_b) shall be defined as the pressure value of the average stresses function at the pipe flow stress. Pipe flow stress equals to SMYS + 69 MPa (10ksi).

14. Fatigue Analysis. For fatigue analysis of each Unmitigated Dent/Corrosion Feature, Enbridge shall utilize FEA to determine stress ranges within the feature resulting from applied pressure cycle, and a stress-cycle (S-N) based fatigue approach to determine the remaining life of the feature. The input variables to the FEA shall be specified minimum yield strength, pipe outer diameter and nominal wall thickness, dent profile from Geometry ILI tool, corrosion effective depth, corrosion effective length, and corrosion width as determined by the metal loss tool. The longitudinal and circumferential stress ranges resulting from an applied pressure cycle from zero internal pressure to maximum operating pressure (MOP) shall be compared and the greater value shall be used for the fatigue analysis. The input variables for the fatigue analysis shall be the maximum stress range from FEA, number of fatigue cycles present in a load-time history (Rainflow counting) based on available pressure cycling data from the pump station immediately upstream of the feature, pressure scaling factor at the location of the feature, and S-N parameters. The S-N parameters corresponding to the BS 7608 Class D mean – 1.0 × standard deviation shall be used for fatigue analysis, as shown in
Equation (1).

$$\log_{10} N = 12.3912 - 3 \log_{10} \Delta\sigma \quad (1)$$

where N is the number of cycles to failure, and $\Delta\sigma$ is the corresponding stress range. The fatigue life of the dent ($Y_{fatigue}$) is the time required to produce a cumulative damage ratio of 1 calculated as shown in Equation (2).

$$\sum_{i=1}^{k} (n_i / N_i) = 1 \quad (2)$$

where k is the number of individual stress ranges in the load spectrum, n_i is the number of cycles that the i^{th} stress range ($\Delta\sigma_i$) appears in the load spectrum, and N_i is the number of cycles to failure corresponding to $\Delta\sigma_i$ as per Equation (1).

B. Calculation of Safety Factors

For each Unmitigated Dent/Corrosion Feature selected for QuAD analysis, Enbridge shall calculate a QuAD Strain Safety Factor, a QuAD Burst Pressure Safety Factor, and a QuAD Fatigue Safety Factor, as provided below in this Section B.1 of this Appendix H.

1. QuAD Strain Safety Factor. To calculate the QuAD Strain Safety Factor ($\gamma_{\mathrm{Q-strain}}$) of each Unmitigated/Dent Corrosion Feature selected for QuAD analysis, Enbridge shall divide the strain capacity characteristic value (C_c) (5^{th} percentile of strain capacity statistical distribution) for such feature by the strain demand characteristic value (D_c) (95^{th} percentile of the strain demand statistical distribution) for such feature, as shown in Equation (3).

$$\gamma_{\mathrm{Q-strain}} = \frac{C_c}{D_c} \qquad (3)$$

The strain demand and capacity statistical distributions of each feature shall be evaluated as per Section A.8 to A.12 in this Appendix H.

2. QuAD Burst Pressure Safety Factor. To calculate the QuAD Burst Pressure Safety Factor ($\gamma_{\mathrm{Q-burst}}$) of each Unmitigated/Dent Corrosion Feature selected for QuAD analysis, Enbridge shall divide the burst pressure (P_b) of the feature (determined in accordance with Section A.13 of this Appendix H) by the Established Maximum Operating Pressure (MOP) of the pipeline (as defined in the Consent Decree) at the location of the feature, as shown in Equation (4).

$$\gamma_{\mathrm{Q-burst}} = \frac{P_b}{\mathrm{MOP}} \qquad (4)$$

3. QuAD Fatigue Safety Factor. In order to determine the QuAD Fatigue Safety Factor ($\gamma_{\mathrm{Q-fatigue}}$) of each Unmitigated Dent/Corrosion Feature, Enbridge shall first calculate the number of years required for such feature to obtain a cumulative damage ratio of 1.0 (Y_{fatigue}) per Section A.14 of this Appendix H. Enbridge shall then divide the Y_{fatigue} value by the sum of the Dent Age plus the Reinspection Interval, as shown in Equation (5)

$$\gamma_{\mathrm{Q-fatigue}} = \frac{Y_{\mathrm{fatigue}}}{(\mathrm{Dent\ Age} + \mathrm{Reinspection\ Interval})} \qquad (5)$$

where the Reinspection Interval is the time in years to the next geometry ILI tool run. For purposes of the QuAD Fatigue Safety Factor calculation, Dent Age shall be determined based on the orientation of each dent: top or bottom side. For top side dents, the Dent Age shall be the time since the earliest reporting of the dent feature by a geometry ILI tool plus the interval since the last geometry ILI tool run prior to detection of the dent. In the absence of previous ILI tool runs, the Dent Age for top side dents shall be the pipe age since the in-service date. For bottom side dents, the Dent Age shall be the pipe age since the in-service date.

C. Identification of Features Requiring Excavation Based On Safety Factor Calculations

1. In accordance with time frames specified in the Consent Decree, Enbridge shall add to the Dig List each Unmitigated Dent/Corrosion Feature that meets one or more of the following criteria:

- Each feature that has a QuAD Strain Safety Factor that is less than 1.25
- Each feature that has a QuAD Burst Pressure Safety Factor less than 1.39
- Each feature that has a QuAD Fatigue Safety Factor less than 4.0

Features that meet one or more of the above criteria shall be subject to the requirements set forth in Table 5 and Paragraph 59 of the Consent Decree. Unmitigated Dent/Corrosion Features that do not meet any of the criteria specified above in this Section C.1 of this Appendix H are not Features Requiring Excavation subject to the requirements of Table 5 or Paragraph 59.

2. If any Unmitigated Dent/Corrosion Feature is added to the Dig List based on the results of a SQuAD analysis in accordance with Appendix G, Enbridge may complete a QuAD analysis of such feature after it has been added to the Dig List. If such a QuAD analysis demonstrates that the feature does not meet any of the criteria specified in Section C.1 of this Appendix H, Enbridge may remove such feature from the Dig List. In addition, if Enbridge completes a QuAD analysis after an Unmitigated Dent/Corrosion Feature has been added to the Dig List, Enbridge may revise any pressure restriction previously established for such feature, to the extent authorized in Paragraph 59.c of the Consent Decree.